third joint of antennæ was gone in his type; in these three female specimens it is the same colour as the preceding ones, long and slender, its first annulation wide, the others tapering off to a point. Walker's type cannot be identified from amongst the three females.

N.B.—The name *chrysophilus* was used by Macquart (Hist. Nat. Dipt. i. p. 194) for an African species; since, however, *chrysophilus*, Walker, is differently derived, both designations may be retained.

Hab. Australia.

? *Corizoneura erratica*, ♂, Walker, List Dipt. pt. i. p. 189 (1848).

Tabanus erraticus, Walker, *l. c.*

This was placed by Walker among the *Tabani*, but it is distinctly a *Pangonia*, Latr.; the eyes apparently bare; it is in very bad condition, the antennæ broken off, one lying on the face.

Hab. North or north-west coast of Australia.

The *Pangonia conjungens*, ♀, Walker (List Dipt. pt. i. p. 140), from Australia, type, is missing.

The *Pangonia lurida*, ♀, Walker, is not a *Pangonia* at all; it belongs to the Tabaninæ.

[To be continued.]

XIII.—*The Hexagonal Structure naturally formed in Cooling Beeswax, and its Influence on the Formation of the Cells of Bees.* By Charles Dawson, F.G.S. &c., and S. A. Woodhead, B.Sc., F.C.S., &c., County Analyst, East Sussex*.

The hexagonal arrangement of the cells of bees has been generally ascribed to a structural instinct. The object of this paper is now to show that the form of the bee-cell is chiefly influenced by a crystalline or pseudo-crystalline hexagonal formation due to the cooling of the wax.

While experimenting with waxes and resins, one of us (Mr. Dawson) noticed that on cooling the mixture had a tendency to arrange itself in hexagonal forms, from which

* Communicated by the Authors, having been read at the Dover Meeting of the British Association, 1899.

he surmised that the outline of bee-cells might be primarily due to the natural structure produced in cooling wax * (fig. 1).

At the instance of Mr. Woodhead, who also recognized the analytical importance of such a discovery, we agreed to work out the details together in Mr. Woodhead's laboratory at the Agricultural College, Uckfield.

It was first of all determined that, although the addition to beeswax of resinous substances gave a more pronounced and bolder outline to the hexagons, no such addition was necessary to beeswax for their production.

If a thin slab of beeswax be melted in a shallow tray (measuring, say, 10 by 8 inches), which is evenly heated throughout and is then placed to cool gradually in a warm atmosphere without draught, hexagonal forms of the ordinary size of a worker-cell of the hive-bee will be seen gradually forming at the bottom of the dish; and a similar line of hexagons will be seen to form on the surface of the wax round the sides of the dish where the wax first cools. The sides of the hexagon are to be seen forming and branching out in advance of the cooling wax, and when a portion of the wax in the centre of the dish alone remains melted the remaining crystals form very rapidly and almost appear to flash out upon the surface.

The tray should be exactly level and the wax about

* The specimens in illustration of this paper may be seen at the Laboratory at the Agricultural College, Uckfield, Sussex.

1·5 millim. thick and of uniform depth, and the atmosphere of even temperature, otherwise the hexagons will be irregular in size and shape.

It is immaterial how thin the plate of wax is, as the hexagons are formed in any case; but their size is undoubtedly regulated by the thickness of the plate of wax, the rule being the thinner the plate the more minute the individual hexagon. The same result may be obtained on a much smaller scale, so as to produce only one or two hexagonal forms; but the operator will then find that the difficulty lies in the rapid cooling at the sides of so small a mass of wax.

The explanation of the formation of these crystalline bodies is as follows:—

On cooling, the wax at first forms into nuclei of nearly equal size. On the shrinking of the wax by further cooling, these nuclei or spheroids are pressed together, forming planes at their points of contact (see longitudinal section, fig. 2). Should the wax be rapidly chilled before these spheroidal bodies are fully formed, they are then prevented from coming into contact one with another by the intervening nebulous masses of "uncentralized" particles of wax *. In this state the nuclei appear when cold as solid circular bodies.

The crystals appear very distinctly above and below the surface while the wax is cooling. When it is actually solid their forms are often very indistinctly seen or may be altogether invisible, but they are none the less present.

The bases of these hexagons, which lie midway between those visible at the top and those at the bottom, are pointed and are arranged so that the point of the base of the upper hexagon coincides with the points of contact of the lower hexagons, as in the honeycomb (see perpendicular sections, figs. 3).

These bases can be observed by making a very thin microscopic section; but several hundred sections had to be examined before they were made out with certainty.

When a small amount of resin and turpentine is added to beeswax and melted, and the mixture is allowed to cool, the outlines of the planes of contact on the hexagons are more distinct and are to be seen raised upon the surface. Under these circumstances they may be easily rubbed with black-lead, which still further increases their visibility.

Our chief experiment was next to put our theory to a practical test, and observe in what manner the bees would

* It would appear from microscopic examination that these particles are also smaller nuclei which become absorbed in the larger. They also, like the larger, assume hexagonal form.

deal with a cast sheet of pure beeswax, which, when viewed by a side light, distinctly showed traces of these hexagons over its surface.

Before introducing it to the bees we had traced upon it with vermilion a group of the hexagons which appeared near the centre of the plate *. This was then photographed, after which the wax plate was placed in an observatory-hive on a bar-frame. The bees soon started upon it, proceeding to excavate round hollows in the centres of the hexagons near the edges of the plate, pushing out on all sides the wax débris around the edge of each excavation. When they reached the planes of contact of the hexagons, either on feeling the minutely raised edges on the surface, or more probably on feeling the increased density of the wax †, the bees determined the limits of their excavation; and it was then discovered by us that the bases of these hexagons were three-sided in the usual form of a bee-cell. Meanwhile a similar process was going on in the cells which lay as nearly as possible in the same irregular wavy line; but the work on one side of the sheet was sometimes considerably more advanced than on the other, the excavation being brought three or four more rows of cells nearer the centre on one side than on the other.

Portions of the débris taken from the centre of the crystal were now kneaded up by the bees into a kind of froth and placed above the lines of pressure or margins of the hexagons, the residue of the débris being put aside for future use.

The portions placed on the margin of the hexagon speedily adhered and solidified; another layer was then added by the bees, and this process was repeated, thus forming a series of strata (which may be noticed under a magnifying-glass on the sides of the complete cells), the bees planing and polishing the inner surfaces of the cell upwards from the base, taking as guides the planes and angles of the hexagons ‡.

In the places where we had traced the outlines of the hexagons in vermilion the bases of the cells were to be distinctly seen formed upon the vermilion outlines. Similar experiments have been repeatedly tried, with the same results.

* We black-leaded another group, with similar results.

† There are two reasons for the density of the wax, namely, the outer edges of the nebulæ are composed of smaller particles, and are therefore more compact, also the pressure brought to bear on the planes of contact renders the sides of the bodies still more compact.

‡ A plate of wax produced by compression and in which no crystals had formed was inserted in the hive; this the bees gnawed to pieces and (?) utilized elsewhere.

In places where the wax plate had been of uneven depth or had cooled too rapidly, the comb presented an irregular appearance, following in form the irregular hexagonal bases beneath, the result being very distinctive and striking to the practised eye of an apiarist.

When in a natural state the newly secreted wax is formed into a small pendent plate, it is probable that the bees crowding around produce the required amount of heat to soften or to keep soft the newly deposited wax, and allow it to cool very gradually when a few hexagonal bodies form within the plate, and these must be soon afterwards hollowed out and built upon. The same process takes place repeatedly against the sides of newly formed hexagons, until the comb is large enough to suit the requirements of the bee, the sizes of the cells being partly influenced and regulated, as above stated, by the rapidity or otherwise of the process of cooling of the wax, and so indirectly, as previously mentioned, by the thickness of the cooling mass*. The size of the crystals may be varied experimentally from those of nearly an inch across to others of microscopic dimensions.

At the time of writing this paper we have not yet succeeded in casting a large sheet of wax containing groups or rows of hexagons so perfectly regular as those which are to be seen in a natural comb or in a comb built upon the ordinary manufactured comb-foundation. We do not pretend, even after many experiments, to be able to cast a foundation of hexagons with the same comparative exactitude as those made by a bee. Although we have little doubt that we may soon be able to do so, we cannot expect in a few limited experiments to compete with the bee, whose seeming aptitude is probably the outcome of ages of natural selection and adaptation. Yet the bees still prefer to adopt our less regular groups or rows of crystals as bases to work upon rather than pull our wax-plate to pieces so as to recast the wax with greater regularity.

A further outcome of our discoveries is that paraffin wax and adulterated beeswax do not assume the same hexagonal form as pure beeswax. We are not aware that other "animal fats" on cooling assume so regular an hexagonal form.

We have succeeded in producing a variety of characteristic forms of these pseudo-crystalline bodies by the treatment of certain waxes with other fats, oils, or waxes. The analytical

* The temperature within a hive, as repeatedly measured by two self-recording thermometers in June 1899 at Uckfield, reached 105° Fahr. without contact with the bodies of the bees.

value of these experiments we hope will prove to be very great both directly and indirectly, and open up an immense field of crystallography in its relation to oils, fats, and waxes.

It has also naturally occurred to us that the formation of certain intricate structures by other insects may be also more or less directly due to crystalline or pseudo-crystalline formation *.

XIV.—*British Amphipoda of the Tribe* Hyperiidea *and the Families* Orchestiidæ *and some* Lysianassidæ. By Canon Norman, M.A., D.C.L., LL.D., F.R.S., &c.

I purpose in these notes to revise the species of British Amphipoda, and at the same time give an account of the Amphipoda procured during the North Atlantic Expeditions of the 'Porcupine,' 'Valorous,' 'Knight Errant,' and 'Triton.' The records of the larger number of the captures of these expeditions will fall under the British species, but in those instances where the species are not members of our fauna, that which relates to them will be enclosed in brackets.

The study of this group of Crustacea has been beset with difficulty, and in consequence of inadequate descriptions and illustrations old records of species must, in some instances, be received with caution. The publication of the splendid work of Professor G. O. Sars has supplied the student with most perfect descriptions and illustrations of the Amphipoda of Norway, which include by far the greater part of those known in our own fauna. If the critic is sometimes inclined to think that occasionally there are to be found in that work divergences described as specific which he would rather regard as varietal, after all it is a mere matter of opinion, and the author has at any rate directed our attention to modifications of character which are worthy of study. In Sars's work we recognize a standard authority, and the arrangement there set forth will here be followed.

I have only given references to such authors and papers as especially throw light upon the species and their more important synonymy. By way of shortening the references to the most frequently quoted authors, the following numbers will be employed. In those cases where the work was included in the list of works and papers on Isopoda lately given by me in the 'Annals' in my paper on "British Isopoda Chelifera"

* The cells of wasps, though hexagonal, have not the prismatic base of the bee-cell. Analysis shows that they contain typical wax crystals.